50X1-HUM

Title: RECENT INFORMATION ON APPLIED EARTHQUAKE STUDIES IN THE USSR (USSR) (V. F. Bonchkovskiy)

Source: Zemletryaseniya, ikh Prichiny, Izucheniye, i Sposoby Bor'by s ikh Posledstviyami, 88 pages, 1949.

50X1-HUM

CONFIDENTIAL

50X1-HUM

RECENT INFORMATION ON APPLIED EARTHQUAKE STUDIES IN THE USSR

V. F. Bonchkovskiy

[Note: The following report was extracted from the monograph "Earthquakes, Their Causes and Study, and Methods of Combatting Their Effects," by Professor V. F. Bonchkovskiy, Honored Scientist and one of the foremost figures in Soviet Seismology. The monograph is one of the popular scientific series published by the Academy of Sciences USSR. The table of contents for the book is as follows:]

TABLE OF CONTENTS

Part VIII. Mechanism of Emergence of Earthquakes

[Extract Translation ~~of Part VIII Entitled "Mechanism of Emergence of Earthquakes"~~ — Figures attached are appended.]

Earthquakes are closely connected with orogenesis and result from sudden shifts, slipping or twisting of matter under continuously acting forces. This concept is confirmed by the geographical distribution of earthquakes and by the severe disturbances of the earth's crust after several catastrophic earthquakes.

At present, after an accumulation of much observational data we can finally approach the problem of earthquakes, of instrumental proof of shifts within the earth, and of the details of the earthquake process. This seismic problem has recently assumed ever-increasing importance, and some results have already been gained. Undoubtedly the seismic mechanism is closely connected with the centrum's physical characteristics, and therefore one should carefully study centra, the movement of matter in them, their spatial position, etc.

The following conclusions were derived from determinations made by Soviet seismologists over a 12-year period of centrum position and depth in Crimean earthquakes: First, epicenters of Crimean earthquakes are located in the Black Sea at an average distance of 40 kilometers south and southeast of the tip of the Crimean peninsula. The seismic activity of these regions is connected with orogenic processes in the Crimean mountain system. Second, these earthquake centra are not randomly disposed, but are contained in a wide stratum which enters the Crimean peninsula from the bottom of the Black Sea.

Figures 1 and 2 confirm the above. This data suggests that Crimean earthquakes are created by progressive shifting of the Crimean mountains massif towards the Black Sea, which assumption is confirmed by geological characteristics as well as by arrangement of centra. From this standpoint, each earthquake should be considered as an instantaneous shift creating mainly transverse waves, and most seismograms of Crimean earthquakes do indicate that transverse waves are considerably stronger than longitudinal. All centra of Crimean earthquakes are shallow and do not appear below the earth's crust, but this does not mean that the sources of movement of the Crimean massif must themselves be located in the earth's crust; on the contrary, it is quite possible that a slow but continuous pressure is exerted in the sub-crust matter.

Another example is the arrangement of centra of Central Asiatic earthquakes, which were also studied by Soviet seismologists. Interpretation of this data is much more difficult since the forms of folding and the movement of the masses of matter which make up mountain systems is much more complex in Central Asia than in the Crimea.

If we systematically divide this region from north to south, we obtain a very interesting picture of the distribution of centra of Central Asiatic earthquakes.

A good example is the segment of the 70th meridian between the 36th and 43th parallels. The curves in Figure 3 show the predominant arrangement of earthquake centra. As seen, centra of normal earthquakes are present throughout the segment. The further south, however, the more frequent the centra of intermediate earthquakes, whose depth increases towards the south.

If we compare this distribution with a geological map of the locality, we conclude that the depth of centra increases under the mountain massifs of the Pamirs. In general terms we can say that the formation of Gindukush and Pamir is due to the slow movement of sub-crust masses, during which fissures and shifts occur not only in the collapsing masses of the earth's crust, but also in the sub-crust matter itself. This explains the presence of several belts in the arrangement of centra. In Central Asiatic earthquakes, the displacements recorded on seismograms for transverse waves were much greater than for longitudinal waves. This again confirms the predominance of shift-like impulses.

A 1939 earthquake in the region of the Peter II range with a centrum 2-3 km deep belongs to this scheme of earthquake formation by the overthrust of some geological structures upon others. Geological studies made by I. Ye. Gubin, worker in the Garm Expedition of the Geophysical Institute, Academy of Sciences USSR, permitted us to compile a detailed picture of the formation of a centrum by faulting of upper strata along the surface of the crystallic foundation, as is shown in Figure 4.

The third example concerns centra of deep earthquakes in the region of coastal belt of the Pacific Ocean, which were studied by Gutenberg and Richter.

According to the map showing the distribution of epicenters of deep-focus earthquakes (Figure 5), very deep centra are found not only beneath the bottom of the Pacific Ocean, but also beneath the Asiatic continent close to shore.

Gutenberg drew up a profile cross-section of the disposition of centra through the Hokkaido Islands, the Japanese Sea, and the coastal belt of Asia, which is shown in Figure 6. The arrangement is similar to that of centra of Central Asiatic earthquakes, except that the depth is considerably greater, reaching 600 kilometers in some cases.

It is difficult to make any sort of definite conclusion without additional data on the geological structure of these regions, but by analogy we propose that here also is a region of slipping both in the sub-crust matter on contact surfaces between continental and sub-crust matter and in the crust itself. These examples illustrate well what can be gained by instrumental study of earthquakes. However, these studies by no means exhaust the field. We have mentioned that the transverse wave, which is created by the displacement process, is much greater than the longitudinal wave, which characterizes the so-called volumetric (bulk) deformation, i.e., the process of compression and distortion of matter. Let us suppose that matter is instantaneously compressed in the centrum which excites the fundamental longitudinal wave. Its energy will be greater or at least equal to the energy of the transverse wave, for the latter occurs as a natural result of the longitudinal wave. The picture would be different if the initial impulse in the centrum created a fundamental transverse wave. This would be the case if the earthquake was caused by dislocation or torsion.

Studies of the amplitudes of longitudinal and transverse waves have just begun. The accurate Kirnos seismographs which have been installed at several Soviet seismic stations will aid in the solution of this problem. The data obtained with their help on local earthquakes will leave no doubt as to the substantial predominance of energy of transverse vibrations. For example, for the after-shocks following the main Askhabad shock of 1948, the energy of transverse vibrations reaching the "Askhabad" seismic station was several times greater than the energy of longitudinal vibrations. Of all cases studied, only in one was the energy of the longitudinal waves approximately equal to that of the transverse waves. This exception is nonetheless of great interest, since it shows that a compressional or distortional impulse is possible in the centrum as well as an impulse of the displacement type.

More detailed studies in the future may reveal the connection of various types of impulses with the geological structure of the locality.

In 1947, earthquakes were recorded for the first time by a special instrument, the extensometer, constructed by Soviet seismologist N. V. Veshnyakov and installed at one of the seismic stations of the Tadzhik SSR. This instrument can record only compressional or distortional bulk deformations i.e., only deformations in longitudinal waves. It might be expected that such an instrument when recording an earthquake would produce the greatest displacement when the longitudinal bulk wave arrived and would not record or would record only weakly displacements when the transverse wave arrived.

Samples of earthquake records produced by the Veshnyakov extensometer and the Kirnos seismograph are shown in Figure 7. They confirm that bulk deformation grows successively in transverse and not in longitudinal waves. This is possibly explained by the fact that the energy of the transverse wave is many times greater than that of the longitudinal wave, and the transverse wave, reaching the earth's surface, causes a secondary longitudinal wave greater than the main longitudinal wave which came from the centrum. This permits us to assume that processes in the centrum are fault-like. Work with extensometers has just begun and analysis of their recordings is still imperfect but it is hoped that in the future they will help to answer clearly the question of the type of movements in the centrum.

Part IX - ~~The~~ Connection of Earthquakes With Other Natural Phenomena

[Figures cited are appended.]

The number and intensity of earthquakes do not show any strict periodicity in their variation. This caused many scientists to look for a connection of earthquakes with other natural phenomena. There is no doubt that such a relationship exists, but it is probably very complex and depends upon many factors, most of which are of second-rate importance; isolation of the dependency for each of these is therefore extremely difficult. For example, it has long been known that earthquakes are much more frequent in winter than in summer and this has been confirmed by many statistical summaries. Comparison of the number of earthquakes in the northern and southern hemispheres with the seasons (Figure 8) gives a very convincing picture.

This relationship might be explained by the fact that cyclonic weather predominates in winter. The atmosphere rests on each square meter of the earth's surface with a force slightly greater than ten tons. If we assume that the pressure in the central region of a cyclone averages 10 mm/Hg below normal, the pressure on each square meter of the earth's surface is

136 kilograms below normal. Consequently, we might assume that this or an even great variation of atmospheric pressure, if it is not the main source of forces acting in earthquakes, is at least an auxiliary factor. This fact was used as a basis for attempts to relate earthquakes to variations in atmospheric pressure. This dependency is shown in Table 4.

Table 4 - Relationship of Earthquakes and Atmospheric Pressure Variations

Change in Atmospheric Pressure (mm/Hg)	12.6	8.8	5.2	1.6	0.4
Number of Earthquakes	148	128	113	103	97

Ye. A. Rozova's comparison of the earthquakes of Central Asia with months of the year (Figure 9) also revealed fewer earthquakes in the summer months. The dependency upon months of the year, which she drew up for the number of earthquakes with surface centra, not only repeated but emphasized this fact. The relationship did not hold for centra of normal depth, however, and for intermediate earthquakes, the number was maximum in the fall months. This is understandable in part, since atmospheric pressure variations, would have the greatest effect upon processes in the upper layers of the earth's crust.

Magnetic field disturbances have frequently been observed during earthquakes. In the Selenginsk earthquake of 1862, the magnetic declination varied by $3\frac{1}{2}^{\circ}$. Disturbance of all magnetic elements was observed in the Czechoslovakian earthquake of 1840. Disturbances of magnetic elements and especially large deviations in magnetic declination have also been observed during many earthquakes in Italy and Japan. Many other examples could be cited. Some foreign authors have pointed out that the "secular behavior" of the magnetic elements is intensified in the region of strong and frequent earthquakes. These facts force us to believe that a relationship between earthquakes and magnetic field disturbances exists, but is by no means observed in all cases. It is very probable that these disturbances are present in most earthquakes, but have not been discovered up to this time because of their low amplitude. The task of contemporary science is to explain this relationship in more detail with the help of very sensitive special instruments for measuring magnetic fields. For this purpose, a detailed magnetic survey of a large seismically-active area has been undertaken in the USSR. When it is repeated after one or several earthquakes, it will permit us to establish the magnitude of magnetic disturbances.

What reasons do we have for our assumption that a relationship exists between earthquakes and magnetic field changes? The first and most natural reasons is that displacements of rocks within the earth's crust, and possibly in the sub-crust matter also, create conditions favorable for redistribution of rocks having magnetic properties, which could not help being reflected in some measure in changes of the magnetic field at the earth's surface.

Another reason is connected with the discovery under laboratory conditions of the changing magnetic properties of some samples under compressional and oscillatory movements. Since one or the other of these conditions always prevails in earthquakes, while compression even precedes an earthquake, it is possible that this effect influences magnetic field variations at the earth's surface.

Optical phenomena and atmospheric-electric effects have also been frequently observed and recorded in various countries both during and before earthquakes. Shortly before or during an earthquake, many observers have seen special luminescence in the form of wide shining bands. Sometimes this luminescence is twinkling and takes on a yellow or green hue. Other observers describe the luminescent effect in the form of rays, comparing them with the northen lights. During the Tashkent earthquake of 1946, Professor Ye. A. Chernyavskiy noted weak luminescence. In the Ashkhabad earthquake of 6 Oct 1948, many residents noted a glow; in fact, it was also observed by some residents of the Firyuz resort, 40 kilometers southwest of Ashkhabad. Two causes can be assumed for these luminescent effects. One of these is collisions and friction between rock fragments, which results in so much heat that the individual particles may be heated to luminescent temperatures. In some cases, it might also be caused by the flare-up of hot gases liberated from fissures in the earth during the earthquake.

The second cause, as Ye. A. Chernyavskiy points out, might be the formation of exceptionally large potential gradients in the atmosphere. The reason for this is that some metals under a pressure of several score atmospheres release positive ions when close to red incandescence, i.e., of the order of several hundred degrees. This applies particularly to iron having admixtures of alkaline metals (about 1%). If we assume the existence of iron at an earthquake centrum several kilometers deep and the ordinary temperature gradient of 3° per 100 meters, the temperature would increase to that of white incandescence and the iron would start to liberate negative charges. On the other hand, the metal by losing a positive or negative charge would itself become negatively or positively charged and could then inductively transmit charges to the earth's surface. These processes could create abnormally high electric field voltage near the earth's surface, which would appear in the form of shining discharges from various sharp-pointed objects (mountain tops, ridges of buildings, etc). Such silent discharges radiate the same weak yellow-green twinkling light that is observed during earthquakes.

Professor Ye. A. Chernyavskiy was able to observe an extraordinarily high electric potential in 1925 two hours before the catastrophic earthquake 120 kilometers from Dzhalal-Abad. The leaves of an electroscope were charged in 1 second instead of 10 or 12 seconds and so strongly that they touched the armature, collapsed, and immediately diverged again. Two hours and twenty-four minutes after an electric storm in Dzhalal-Abad the first shock with a force of 4 [redacted] was felt, and after $1\frac{1}{2}$ hours the second shock with a force of 6 and underground noises occurred, this one being felt in Dzhalal-Abad. A similar case of anomalous behavior of the electric potential was observed in Tashkent during the destructive earthquake in the Chatkala range in November 1946. This interesting dependency, however, still cannot be considered accurately established and further study of it is required.

Many earthquakes are preceded or accompanied by sounds in the form of a low-frequency rumble or noise. The intensity of the sound is independent of seismic intensity. The sound effects take place in the earth's crust, and the main reason for this sound is in the earth's crust, although the sounds have been heard in both water and air. The reason for the sound in earthquakes is the oscillations of the terrestrial layers with a very small period at the moment of the earthquake in the centrum. It is very probable that at first the sound wave comes to the place of observation from the centrum directly through the earth's solid crust. Sound waves also arrive at the epicenter and at other points on the earth's surface. They in turn excite sound waves in the atmosphere, which are propagated along the earth's surface and also reach the place of observation. Thus, at the observation point, we obtain a complex sound effect lasting for several seconds.

The following scale-of-five might be used in evaluating sound effects during earthquakes:

1. A weak rumble, heard only when the surroundings are absolutely quiet and the ear is held to the ground.

2. A weak rumble heard in air and heard more strongly when the ear is held to the ground.

3. A rumble of average strength heard even in enclosed surroundings.

4. A loud rumble causing unrest in people.

5. A very strong rumble and thunder causing unrest and fear in people.

Because of the lack of accurate observations, the picture of sound distribution at the earth's surface has not been established. What is available indicates that this distribution is extremely complex.

Finally, we mention the connection between earthquakes, the earth's rotation, and lunar phases which has been proposed by some scientists. Opposite conclusions have been obtained. The supporters of such a relationship point out the liquid state of matter in the inner part of the earth and the tide phenomena in it under the influence of the moon and sun's attraction. The existence of tides in the earth's crust has been established by instrumental observations; the magnitudes are so negligible, however, that they prevent any positive conclusions. Solution of this problem requires processing of voluminous data of observations, some of which have not yet been undertaken.

[Part X - Forecasting Earthquakes]

The problem of forecasting earthquakes is considered from two standpoints; namely, forecasting the site and intensity of a possible earthquake without indications of the time, and forecasting the time of the earthquake on a certain territory.

Forecasting earthquakes from the first standpoint can be considered solved, although requiring some corrections in connection with new geological and seismic data. This forecast is based on the processing of much systematic material of direct observations over many years. Naturally, it is impossible to collect homogeneous material for all points of a seismically active region, but generally a great deal of material is available for important places such as large cities.

On the basis of this statistical material, we can always indicate the force with which an earthquake will appear in a certain place and the frequency of strong and catastrophic earthquakes. When this data is entered on a geographical map of a certain country or the world, we can isolate the possible regions having earthquakes with a force of 12, 11, 10, 9, etc.

A regional seismic map of the USSR was drawn up by G. P. Gorshkov in 1937. It was discussed at a special conference at Yerevan in 1948 and approved after some additions and changes. The regional seismic map is a very important document, since it can be used to determine the seismic activity of any ~~location~~ area ~~of~~ in the USSR, which is very important in developing anti-seismic measures in construction.

The final draft of the map is shown in Figure 10. We see that a considerable area of the USSR undergoes catastrophic earthquakes, particularly the regions along the southen boundary. In the west, the seismic-active belt lies in the Carpathians and then passes east through the Crimea, Caucasus, Caspian Sea, Kopet-Dag, T'ien-Shan, and Pamirs. Thus all the Central Asiatic republics are seismically-active and include some zones of very high intensity. In the east the seismically-active regions are located in the land around Lake Baykal and also in the Far East, Sakhalin, Kuriles and Kamchatka.

How can the problem of forecasting the time of earthquakes be solved? Unfortunately, despite many attempts of scientists of various countries, this problem remains unsolved. There has been some progress in this direction, but accurate forecasts remain a long way off.

The first method of forecasting the time of an earthquake is that of listening to various sounds and noises in the earth's crust. This is one of the oldest forecasting methods. It is based on the assumption that every major disturbance in the earth's crust which is connected with tension in its layers is preceded by minor disturbances (individual faults, fissures, etc), which, while they do not produce an earthquake, are the preparatory process for one. These preliminary disturbances create sounds or noises, which can be detected by a sensitive sound-receiver. While the idea is sound, its technical implementation is very difficult.

This method was first used by Italian scientists to forecast volcanic eruptions. Their sound-receiving apparatus, placed at a certain depth beneath the earth's surface close to Mt. Vesuvius, indicated noises and sounds. In California a hydrophone was installed at a depth of 110 meters in a water-filled shaft. The apparatus transmitted a weak scrunching sound and comparatively stronger rolling booms and crackles, but the Americans, like the Italians, did not arrive at any positive solution of the problem. This naturally does not mean that this method is useless but rather that the sound-receiving units did not conform to the task set up. We are confident that a sound-receiving unit installed at a great depth and capable of giving us a picture of the change of sounds of different frequencies, both high and low, will be valuable in the practice of forecasting earthquakes. Construction of such a unit requires a good deal of preliminary research work, however.

The second method lies in studying tilts of the earth's surface as predecessors of earthquakes. Tilts can be measured by instruments with very little error, i.e., not exceeding 0.1'' of an arc; these measurements have been made in various countries. In the USSR there are several regularly-operating tilt-measuring stations in seismic regions, and their number is continuously increasing. Since tiltmeters record tilts of the earth's surface which are connected with external causes (distribution and change of atmospheric pressure, change of soil temperature, precipitation, etc) as well as tilts connected with orogenesis and pre-earthquake processes, it is naturally very difficult to eliminate from the overall tilt records those tilts which are connected with the above-mentioned external causes.

The following conclusions can be made on the basis of the above:

1. If a strong earthquake occurs within a radius of about 100 kilometers of a tiltmeter station, the behavior of tilts of the earth's surface caused only by internal reasons has a sharply-defined irregularity in its movements, the so-called "tilt storm".

2. "Tilt Storms" occur 3-10 days before earthquakes.

We should however point out that these conclusions are still preliminary and require confirmation by further data. In addition, one tiltmeter station does not indicate the earthquake site but an area 100 kilometers in radius. Further studies in this direction will apparently require a thick network of tilt~~measuring~~meter stations in order to determine the possible region for forecasting earthquakes.

The third method is to study the variations in the elastic properties of the intratelluric substance in connection with an increase in compressional forces before an earthquake. An approaching catastrophe can be revealed by continuous observations of the variations in these elastic properties. This method of study is very difficult, however. There has been an attempt to determine the speed of propagation of seismic waves through the deep layers of the earth's crust before and after an earthquake; results were positive, i.e., a difference was noted in the speeds before and after. This method has not been further developed so far, but it is physically sound and should be tested with contemporary techniques.

The fourth method, i.e., observations of disturbances in the electrical state of the atmosphere, has not been sufficiently developed at present. This method is based on observations of the appearance of electromagnetic waves before and during an earthquake. These observations have been haphazard, however, and no systematic studies of the electromagnetic waves appearing before an earthquake have been made. Some scientists assume that the often observed unrest of animals before an earthquake is the result of these electromagnetic waves acting upon the nervous system of the animals.

We could name several other physical phenomena as possible indices for forecasting earthquakes, but all these are not yet sufficiently studied and observations have not been checked.

From the above, it is clear that accurate forecasting of earthquakes is impossible at the present time, but it is hoped that the high sensitivity of present-day physical instruments and the availability of several different phenomena as earthquake indicators will solve this problem.

[redacted]

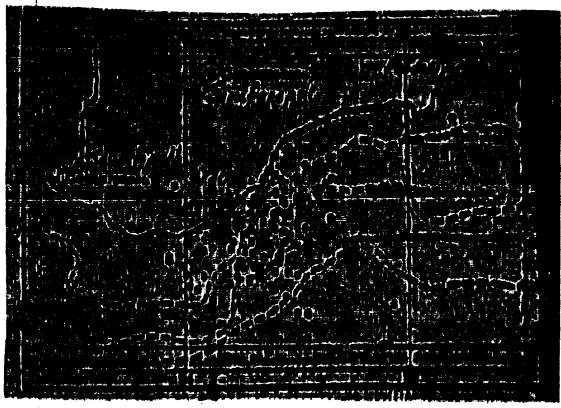


Fig. 1. Epicenters of Crimean Earthquakes 1928-1941 (Drawn Up by A. Ya. Levitskaya)

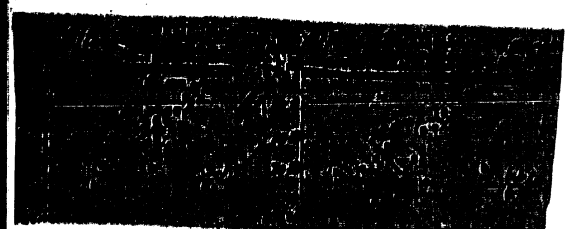


Fig. 2. Distribution of Centra of Crimean Earthquakes

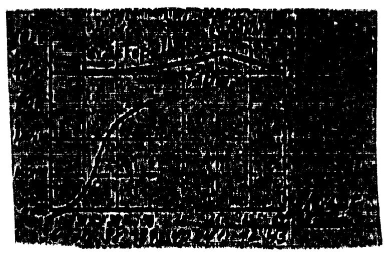


Fig. 3. Average Lines of Depth of Earthquake Centra Along the 70th Meridian

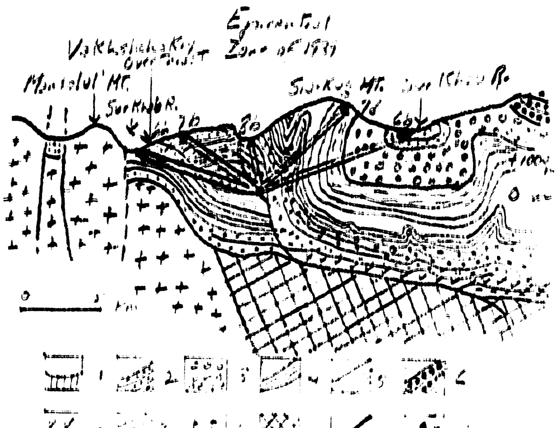
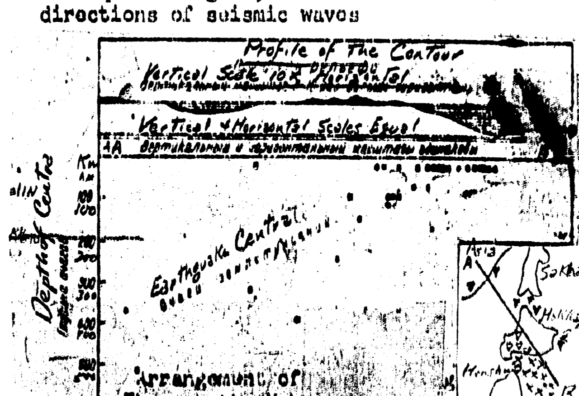


Fig. 4. Geological Profile of Northern Slope of Peter I Range. Earthquake of 1939 (drawn up by I. Ye. Gubin in 1946 1-8, surface strata; 9-granites; 10-ancient deposits and igneous rock; 11-lines of faults and overthrusts; 12-earthquake diagram, double lines are directions of seismic waves



~~and the Coast of the Asiatic Continent~~

~~[illegible] 1940 [illegible] Chm- [illegible] han; [illegible] d~~

~~Fig. [illegible] A. Rozova [illegible], Alma-Ata, Chm- [illegible] of Normal Depth [illegible] Stations~~

Fig. 6. Arrangement of Centra Along a Line Through the Hokkaido Islands and The Coast of the Asiatic Continent, Key to Diagram in Lower Right Corner - X - Shallow, ▽ - Intermediate, ♥ - Deep-Focus Earthquakes

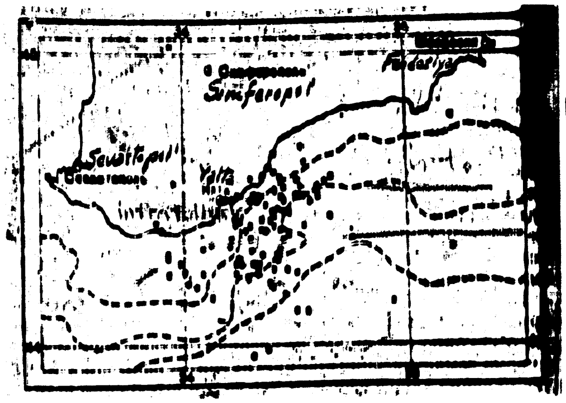


Fig. 1. Epicenters of Crimean Earthquakes 1928-1941 (Drawn Up by A. Ya. Levitskaya)

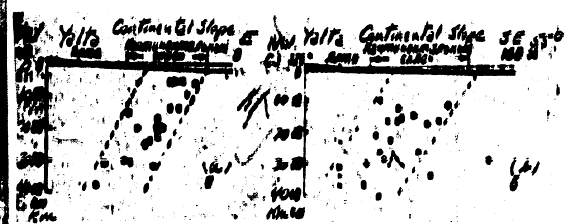


Fig. 2. Distribution of Centra of Crimean Earthquakes

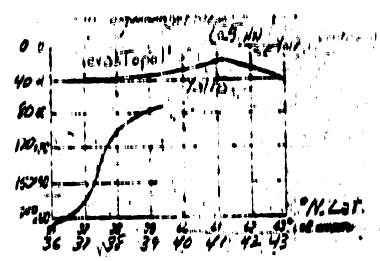


Fig. 3. Average Lines of Depth of Earthquake Centra along the 70th Meridian

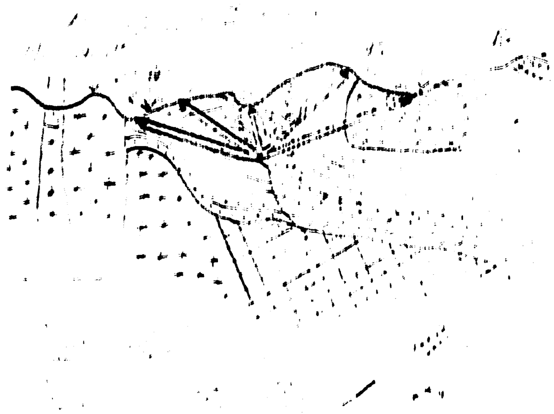
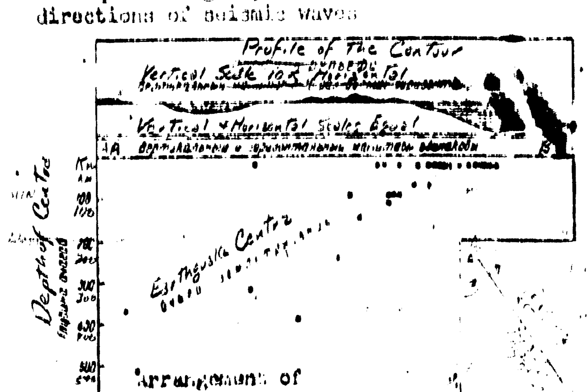
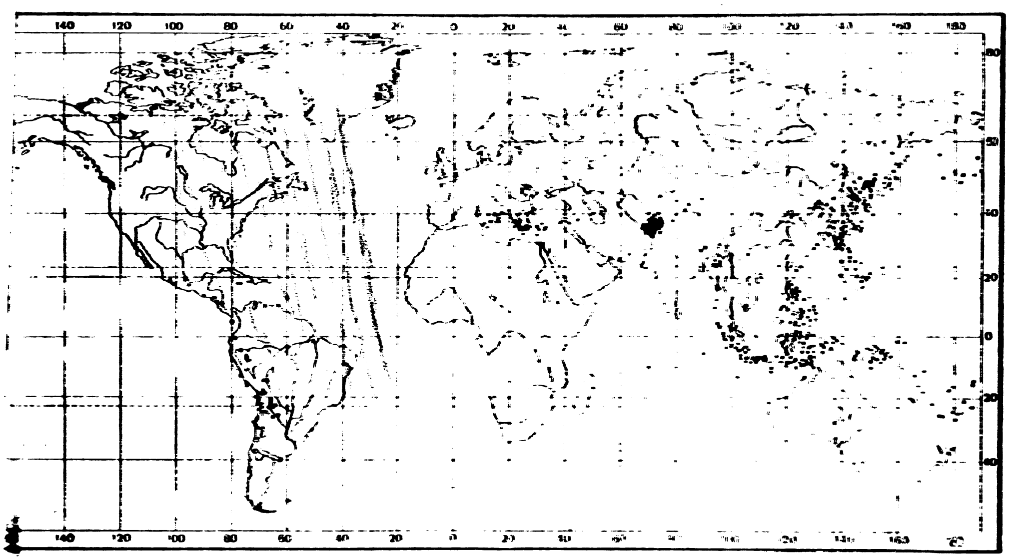


Fig. 4. Geological Profile of Northern Slope of Peter I Range. Earthquake of 1939 (drawn up by I. Ye. Gubin in 1946 1-8, surface strata; 9-granites; 10-ancient d posits and igneous rock; 11-lines of faults and overthrusts; 12-earthquake diagram, double lines are directions of seismic waves



Arrangement of ~~Through the Ho~~ ~~and the Coast of the Asiatic Continent~~

~~Fig. ... epicen- ters of central ... for 1939-1940 (... Moscow) ... Chim- Chimkent ... -andijhan; ... Samarkand; ...~~



Карта распределения [illegible]

Fig 5 Map of Distribution of Deep-Focus Earthquakes (drawn up by N. A. Linden).

Key: X - focus depth from 0-140 Km;
0 - 150-340 Km;
● - 350 Km & more.

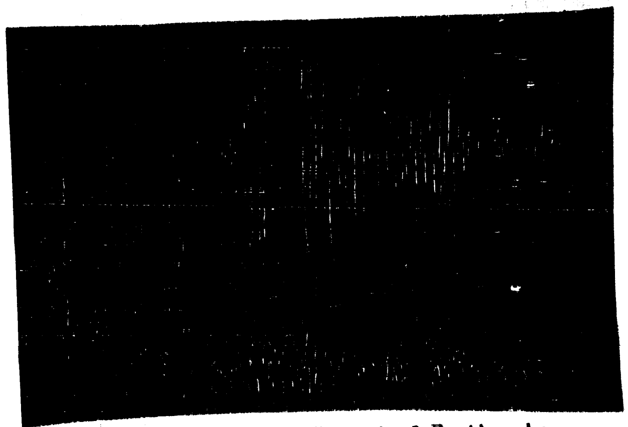


Fig. 7. Simultaneous Record of Earthquakes in Obi-Garm by the N. V. Veshnyakov extensometer (I) and a D. P. Kirnos seismograph (II)

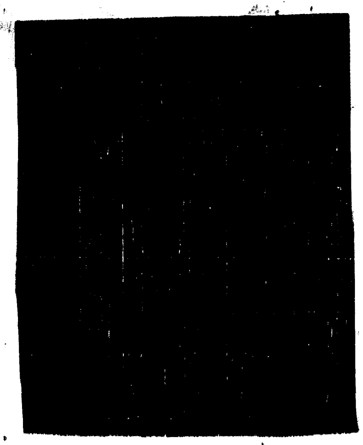


Fig. 8. Number of Earthquakes According to Months of the Year. Dotted Line-Perceptible Earthquakes; Solid Line-Catastrophic ~~Catastrophic~~ Earthquakes Registered

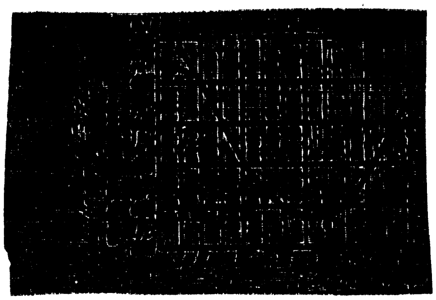


Fig. 9. Number of Earthquakes in Central Asia According to Months of the Year

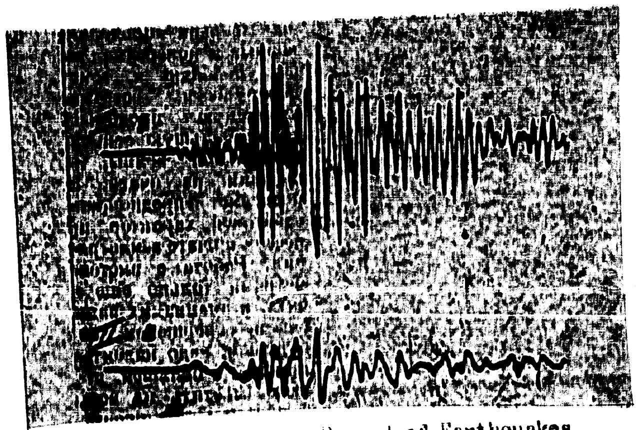


Fig. 7. Simultaneous Record of Earthquakes in Obi-Garm by the N. V. Veshnyakov extensometer (I) and a D. P. Kirnos seismograph (II)

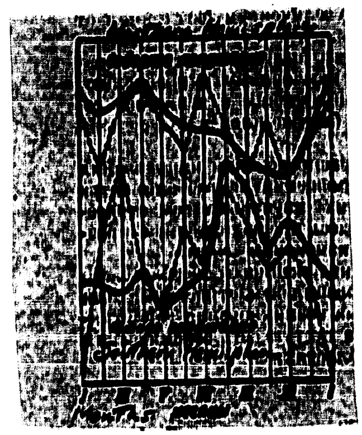


Fig. 8. Number of Earthquakes According to Months of the Year. Dotted Line-Perceptible Earthquakes; Solid Line-Catastrophic ~~Catastrophic~~ Earthquakes Registered

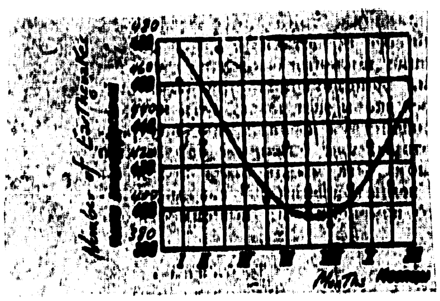


Fig. 9. Number of Earthquakes in Central Asia according to Months of the Year

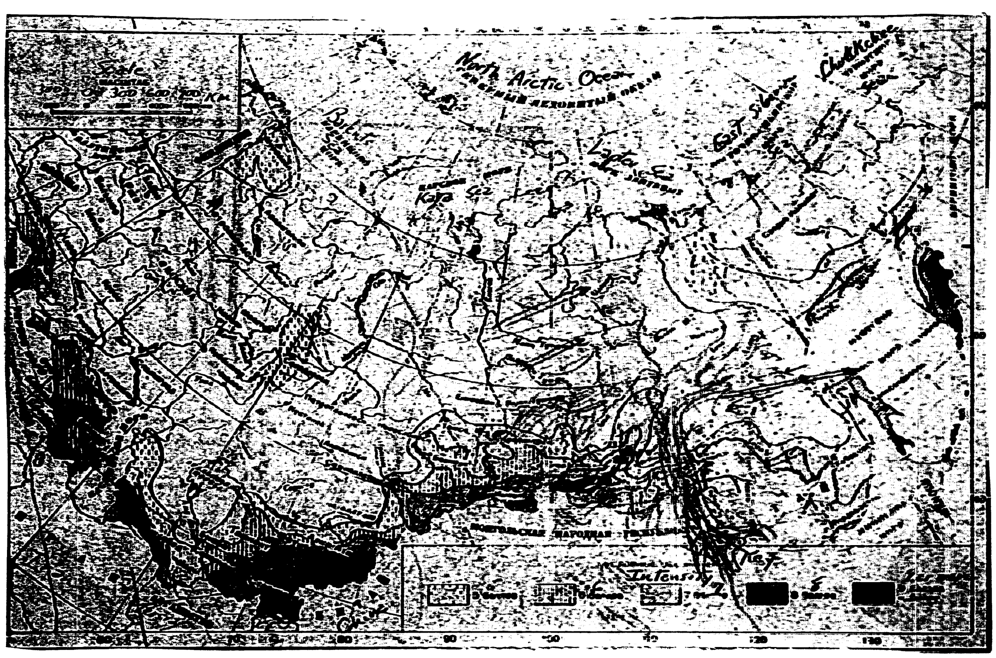


Fig 10 - Diagram of Seismic Regional Division of The USSR - 1949
Drawn up by G. P. Gorshkov with the help of I. Ye Gubin, A. Ya. Levitskaya, N A. Linden, S.V. Medvedev, Ye. A. Rozova, A.D. Sabinina, Ye. F Savarenskiy, V. G Tishchenko, and others. Edited by Professor V. F. Bonchkovskiy

- END -